Cruise Report
F.S. ALKOR Cruise No. 03/12

Dates of Cruise: 23. September to 26. September 2012

Projects:
Student course in phys. oceanogr.

Areas of Research: Physical oceanography
Port Call: Warnemünde (23./24. Sept. 2012)
Institute: CAU Kiel & GEOMAR Helmholtz Zentrum für Ozeanforschung Kiel
Chief Scientist & Report responsible: Dr. J. Karstensen (GEOMAR)
Number of Scientists: 12 & 12
Master: Norbert Hechler

Chapter 1

Scientific personal

Cruise code: AL 03/12
Cruise dates: 23.9. – 26.09.2012
Port call: Kiel – Warnemünde – Kiel

Table 1.1: *Scientific personal AL 03/12: GEOMAR: Helmholtz-Zentrum für Ozeanforschung Kiel, Kiel, Germany; CAU: Christian Albrechts Universität Kiel, Kiel, Germany*

Name	Institute	Function	leg
Johannes Karstensen	GEOMAR	Chief scientist	1, 2
Uwe Koy	GEOMAR	PO	1, 2
Svenja Reinlein	CAU	Master student	1, 2
Sandra Tippenhauer	GEOMAR	PhD student	1, 2
Miriam Plöger	GEOMAR		1, 2
Robin Stechert	GEOMAR		1, 2
Joost Hemmen	CAU	PdE student	1
Patrick Wagner	CAU	PdE student	1
Theresa Diefenbach	CAU	PdE student	1
Momme Lenning	CAU	student	1
Franz Phillip Tuchen	CAU	student	1
Benjamin Schmidt	CAU	student	1
Silja Karoline Flenner	CAU	student	2
Clara Stolle	CAU	student	2
Samuel Eberenz	CAU	student	2
Jan Luedke	CAU	student	2
Jefim Vogel	CAU	student	2
Milan Kloewer	CAU	student	2

Chapter 2

Objective

The main purpose of the ALKOR cruise 03/12 was the training of students in observational methods for physical oceanographers. Undergraduate students in the Bachelor programm ”Physik des Erdsystems” are introduced into modern observational techniques in physical oceanography, including instrument calibration and interpretation of observations. The course (MNF-Pher-110b) is part of the ”Messmethoden” lecture. IThe cruise will give the students an opportunity to experience the work and life at sea and also to explore and investigate physical oceanography processes in the western Baltic Sea, the ocean at their backyard.

The scientific motivation of the cruise is to obtain a rather synoptic picture of the hydrography and water movement in the western Baltic. Hydrographic and current sections from the Fehmarn Belt (section C) and along the deepest topography from about 10°40 E to 14°21 E (section L) were done. Moreover, a long time mooring site that monitors the flow through the Fehmarn Belt is serviced.

Chapter 3

Cruise Narrative

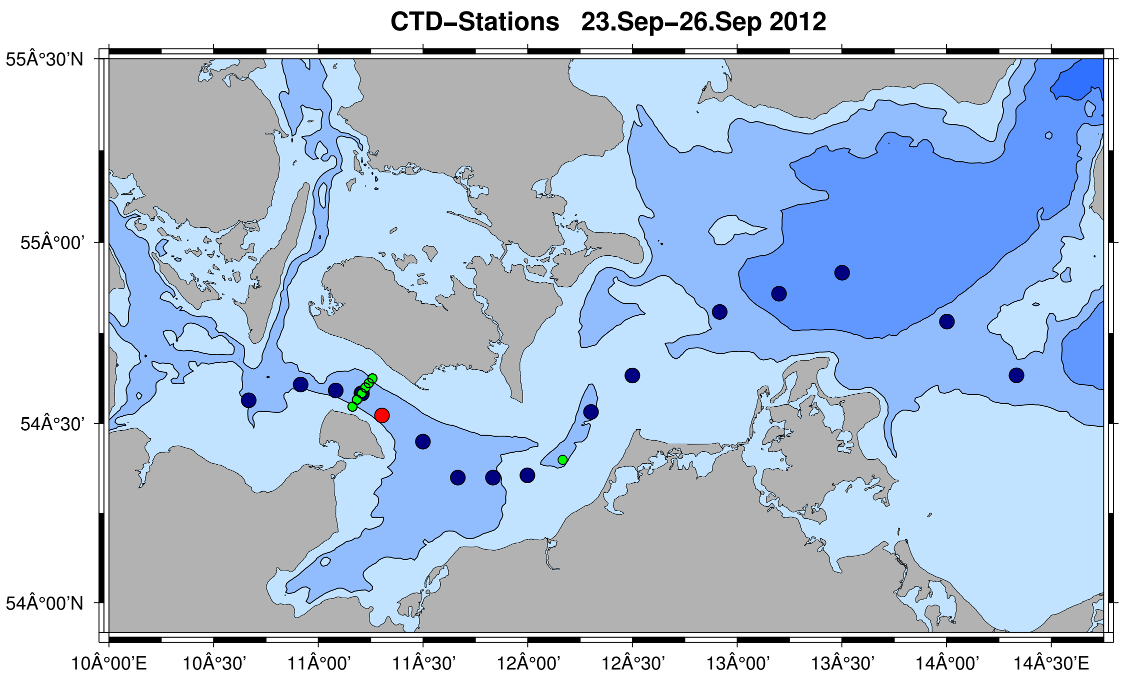

Figure 3.1: *ALKOR 03/12 cruise stations. Black (LG section)/ Green (FB section) and Red dot are the CTD stations, red dot is also location of the V431 mooring.*

DAY 1 (Sunday, 23.09.2012):
We left Kiel Westufer at 08:15 (all times in the cruise narrative are local time Kiel) with a light breeze from northeats and under sunny conditions. Shortly after leaving the port, Rainer Nausch, the first officer, did his safety instruction and introduced the new scientific crew to the ships facilities and rules. A short introduction of the planned program for the following days was given. Ship ADCP (hull mounted 600kHz) and TSG were switched on. After about 2 hours of steaming we reached the first CTD test station and all scientific crew participated in the station. All 12 bottles where fired and a larger volume of water was collected to be later used as“Substandard”

for tracing the stability of the Beckman Salinometer.
Three more stations in the 'L' section were occupied, the last one in the Speergebiet Marienleuchte, where the V431 mooring is located. After a CTD at the mooring position we send the release command for the mooring. Unfortunately, even after sending the release code multiple times the mooring was not spotted at the surface and we finally decided to stop the operation and to start the C section over the Fehmarnbelt (including a 7kn ADCP optimized section).
As the weather forecast was predicting 8-9bft (with gust 10bft) for Monday, it was decided to steam to Warnemuende and look for shelter there. The last CTD, that was also part of the 'L' section, was occupied at 20:30 and we transit to Warnemuende. We reached WarnemÃ¼nde passanger pier P2 at around 22:00.

DAY 2 (Monday, 24.09.2012):
We stayed for the whole day at the passgier pier in Warnemuende. At 09:00 we started to analyse the salinomter bottle samples from Sunday. This included probes from the rosette, the thermosalinograph, and bottles of substandard water collected with the first cast. After an introductory session where all students participated, the analysis was done in groups of two students each. Moreover, the CTD and underway data was processed up to a level at which allowed the students to start the excerises. At 16:30 the second group of students arrived and the first group (#1) left. After dinner, at 18:15 another salinometer session was started with the new group (#2) that continued until 20:00.

DAY 3 (Tuesday, 25.09.2012):
Leaving Warnemuende at 07:50 we headed towards the closest CTD station on the 'L' section off Warnemuende. As a new goup of students was on board an introduction to the CTD work was done with all students. The rest of the day, until 21:20 we suveyed all standard stations along the L Section towards the east (until Praktikumsstation #21). Over night we headed back to start CTD work again on Wednesday. In parallel to the CTD work, the bottle and TSG samples were analysed with the Salinometer. Either at a CTD or every hour the meteorological observations were done.

DAY 4 (Wednesday, 26.09.2012):
At 06:50 we arrived at Praktikumsstation # 13 and started with the CTD survey and meteorological observations again, surveying westward, towards the Fehmarnbelt. We stopped at the Speeregbiet Marienleute and searched for the V431 mooring again - but unfortunately without success. The second CTD occupation of the C section followed. At 12:10 we headed back to Kiel were we were moored at Kiel Westufer pier. All equipment was unloaded.

Chapter 4

Preliminary results

4.1 Hydrographic and currents along C and L section

Fehmarn Belt (C section)

The hydrology of Fehmarn Belt was measured twice during the cruise. Each time, six CTD profiles were taken between 54°32.8 N, 11°09.8E and 54°37.5N, 11°15.5E.

The hydrology of Fehmarn Belt was measured twice during the cruise. Each time, six CTD profiles were taken between 54°32.8'N, 11°09.8'E and 54°37.5'N, 11°15.5'E.

The first section from sunday, 23 September 2012 (Fig. 4.1, left), shows a rather homogenous structure in the top 20 m of water in Fehmarn Belt with potential temperatures of 14 to 14.5 °C. There appears to be a slight meridional gradient in temperature in the top layer. This could be due to diurnal heating since the profiles were taken between 11 am and 2 pm local time from south to north and there was no constant cloud cover. Salinity in the top 10 m is higher in the central belt then towards the coasts on each sides. The most striking feature in salinity and temperature is a high salinity and low temperature core between approximately 20 m and the sea floor, concentrated in the north of the belt. This feature also appears in the density structure. The density appears to be dominated by salinity with a strong maximum in the core of salty water at the bottom of the belt. The concentration of oxygen (Fig. 4.1, left) in the water is homogenous with values between 6 and 6.5 ml/l. It shows maximal values in the core of salty water and in the southern surface layer. Lowest oxygen concentrations were observed at the bottom south of the salty core and in the northern surface layer. The highest concentrations of chlorophyll A are between a depth of 5 and 18 m.

While Saturday and Sunday were dominated by moderate winds from the west and south-west, the western Baltic Sea experienced strong winds easterlies on Monday and winds from the south on Tuesday and Wednesday. As a result of this, the Fehmarn Belt section of Wednesday, 26 September 2012 (Fig. 4.1, right), shows quite different characteristics than the first one. Please note, that the interpolation in the contour plots could be missleading between the two southern-most profiles from September 26. This becomes most visible in Fig. **??** (lower right) where the interpolation calculates an unstable stratification. The potential temperature is still homogenous at 14 to 14.5 °C in the top 20 m but the core of cold and salty water at the sea floor shifted 2'

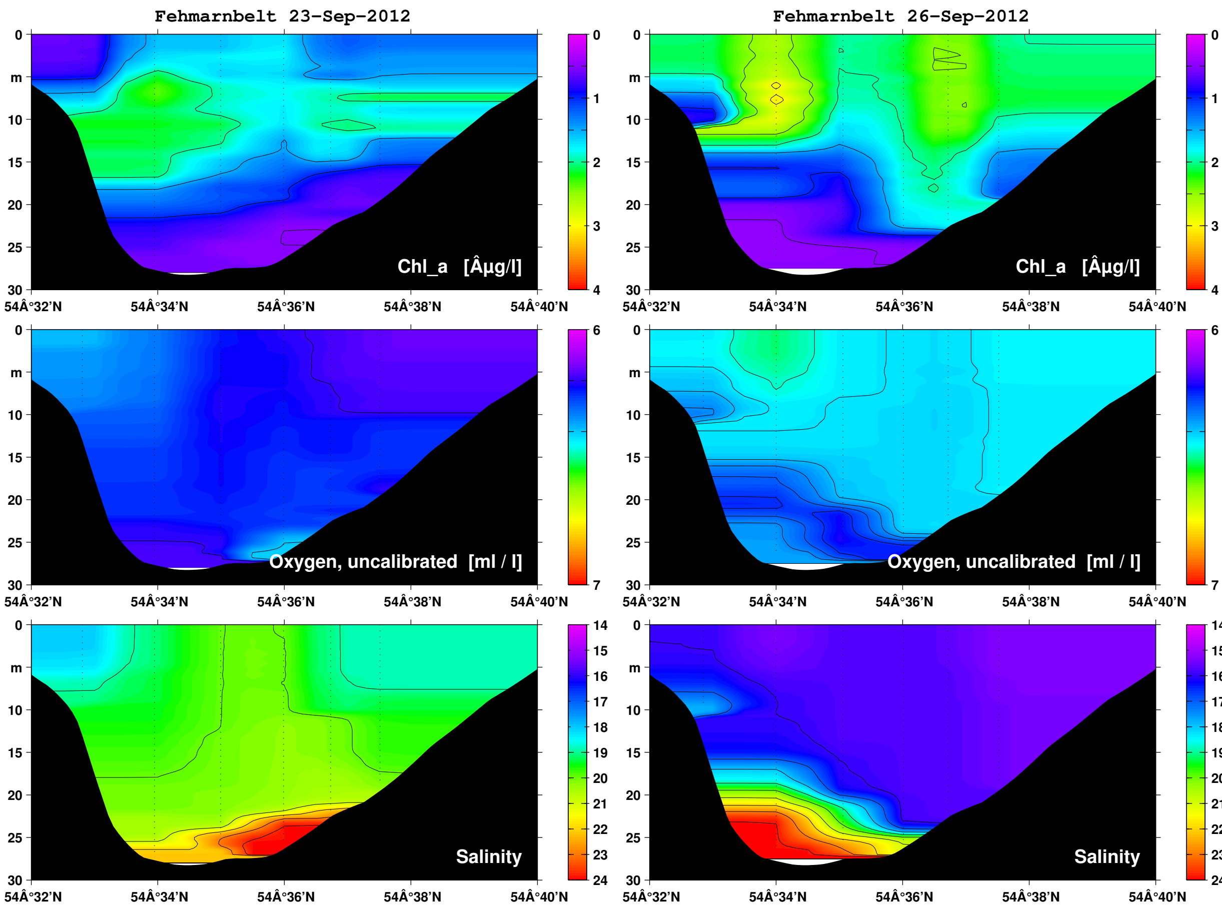

Figure 4.1: *Chlorophyll, oxygen and salinity distribution along Fehmarn Belt. Left: 23. Sept. 2012, right: 26. Sept. 2012.*

latitude to the south and salinity in the mixed layer decreased from approximately 19 to 16 in the southern and 15 in the northern part of the belt. This notable freshening could be due to brackish water from Arkona Basin pushed into the Belt Sea by the strong easterly winds two days before on the 24th of September. Furthermore, the concentration of oxygen increased slightly almost over the whole water column (Fig. 4.1, right) and more chlorophyll-a appeared, especially in the top 15 m of the water column.

The core of colder and saltier water at the sea floor is possibly related to an inflow of North Sea water. The increased concentration of oxygen supports this assumption since inflow water originates from the ventilated surface layer of the North Sea. There is a strong horizontal gradient in potential density between the core of inflow water and its surrounding. Hence the core is supposingly a dynamic feature with a velocity which is orthogonal to the section (geostrophic balance). Applying thermal wind equation would yield flow towards south-east on the 23rd and flow towards north-west on the 26th. The meridional shift of the core could be due to a change in wind forcing influencing the pathway of inflowing water.

Zonal section (L Section)

The zonal section (Fig. 4.2) shows the temperature, salinity, density, chlorophyll and oxygen distribution between Fehmarnbelt and Arkona Basin from September 23 to September 26 2012.

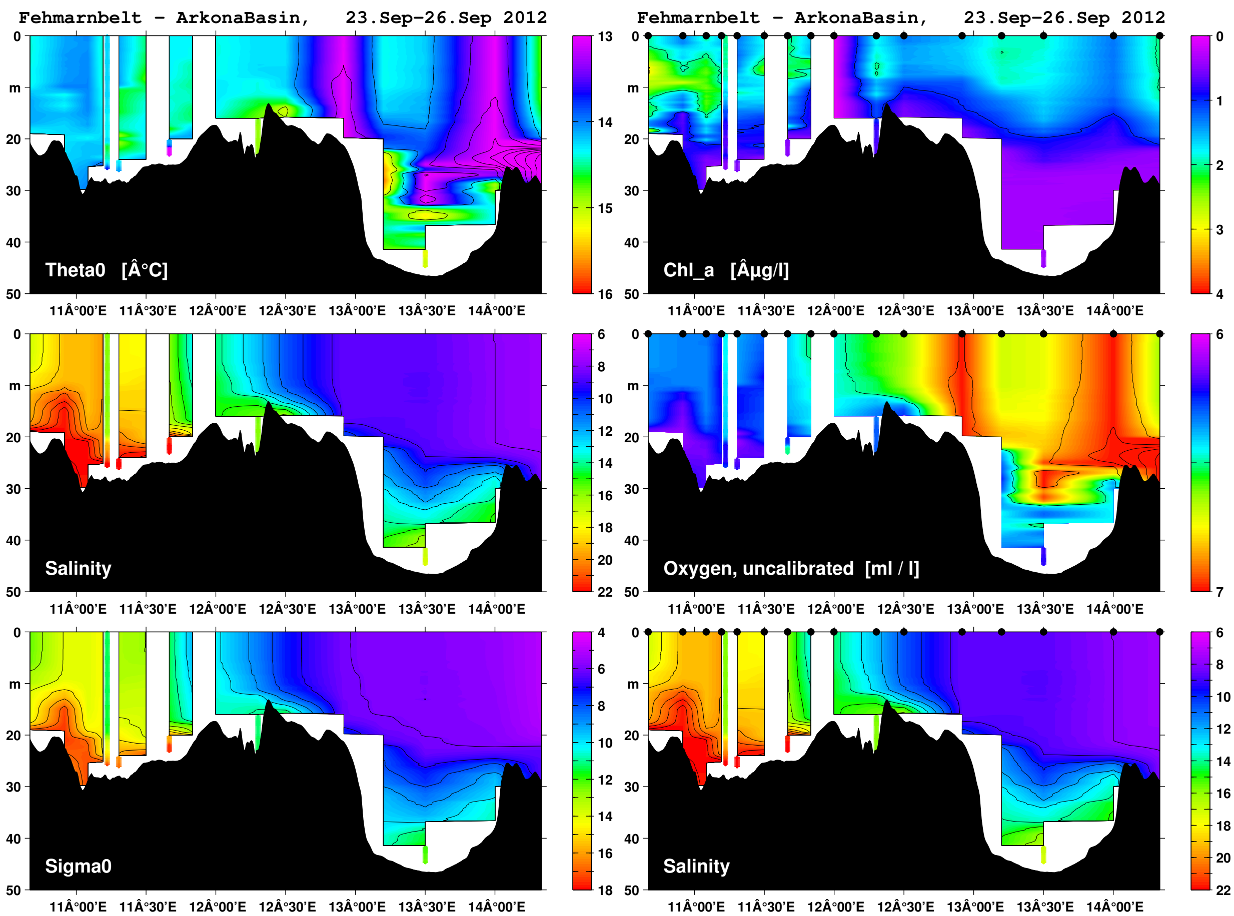

Figure 4.2: *Potential temperature, salinity and potential density distribution along zonal section. 23. Sept. to 26. Sept. 2012.*

The temperature distribution (Fig. 4.2, upper left) in the section ranges from 12 to 15.5°C, the minimum is found in the upper 30m. Please note, that the measured minimum of less than 12°C is out of range in the color scale. The horizontal gradients in the upper 20m were measured by the ships TSG as well. The maximum of about 15.5°C is located in the lower meters in the Arkona Basin, where the stable stratification might seperate these water masses from the cooling processes at the surface.

The salinity distribution as shown in Fig. 4.2 (middle left) is typical for the Baltic Sea, ranging from 6 to 22. Freshest water masses are located in the eastern part of the section, which come from the central Baltic Sea. The horizontal salinity gradient sets up due to the incoming water masses from the North Sea with a salinity of up to 22 PSU. The higher density of North

Sea water explains the vertical density gradient, as the denser water is located below the fresher central Baltic Sea water.

The density distribution shown in Fig. 4.2 (lower left) is mainly dominated by salinity. Temperature variations within the section appear in a smaller range compared to salinity variations, whereas the temperature seems to have little influence on density.

The chlorophyll distribution (Fig. 4.2, upper right) does not reach below 20m. The highest concentration is found in the western part of the section. In the Arkona Basin, the concentration displays the same pattern as the temperature distribution, with high concentrations of chlorophyll coinciding with higher temperatures.

The oxygen distribution (Fig. 4.2, middle right) is mainly anti-correlated with the temperature distribution. This can be explained by the higher solubility of oxygen in colder water. Hence, the oxygen maximum coincidences with a minimum in temperature. The high concentrations of oxygen down to 30m might be explained due to turbulent mixing during the stronger winds in the last days.

4.2 Meteorological observations

Analyzing oceanographic data requires detailed knowledge about the meteorological conditions prevailing at the time of the respective oceanographic measurements.
In the following the data that has been automatically recorded from DAVIS-ship system, as well as, direct observations and surface pressure charts, obtained from metoffice.gov.uk, are used to investigate the predominant weather conditions during our cruise.

More precise, our interpretation is based on the time-series of air pressure, wind speed, wind direction, air temperature and radiation.

The first day of our cruise (September, 23) was dominated by mild weather conditions with air temperatures between 14°C and 15°C. The big low pressure cell above Finland/ Russia (Figure 4.3) forced northwesterly winds with wind velocities between 6 ms^{-1} and 8 ms^{-1}.

Figure 4.4 shows very high incoming/shortwave radiation for September, 23, which means that the cloudiness was very small during the day. In our direct observations the estimated value for the cloud amount was $\frac{3}{8}$. In the night from September, 23 to September, 24 several smaller highpressure areas passed over, causing veering wind. From now on the situation is dominated by a low pressure area, resided over the North Sea. The pressure field evolves southeasterly winds with wind speeds up to 12 ms^{-1}. Air temperature ranges from 9°C to 13°C. The small incoming solar radiation indicates high cloudiness. The low wind velocities in the night from September, 24 to September, 25 can be explained by far distances between isobars, which indicate low pressure gradients. Frontpassage yields precipitation and high wind velocities with gusts up to over $12ms^{-1}$. Figure 4.4 shows a warming trend during September, 25, with a maximum temperature of about 16.5°C in the evening. This could be ascribed to the cloud amount of $\frac{7}{8}$ to $\frac{8}{8}$, which was observed during the past two days.

Apart from the calm at night and a slight cooling trend the situation on September 26 does not

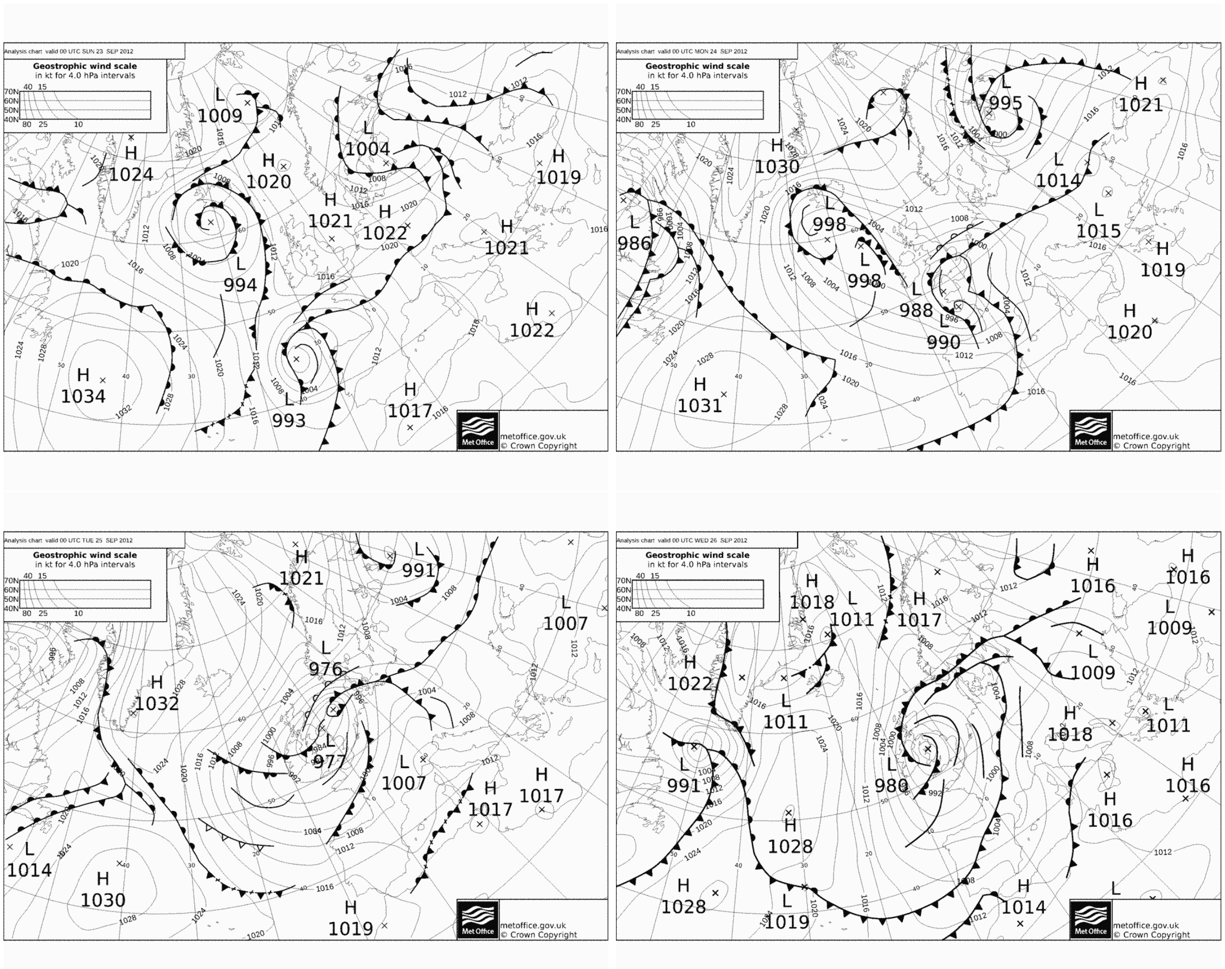

Figure 4.3: *Surface pressure analysis charts from MetOffice for the period September, 23 to September 26, 2012*

change much compared to the weather conditions the day before. Both, the calm and the cooling trend, can be hardly explained by our given data. We have still observed absolute cloudiness in the morning.

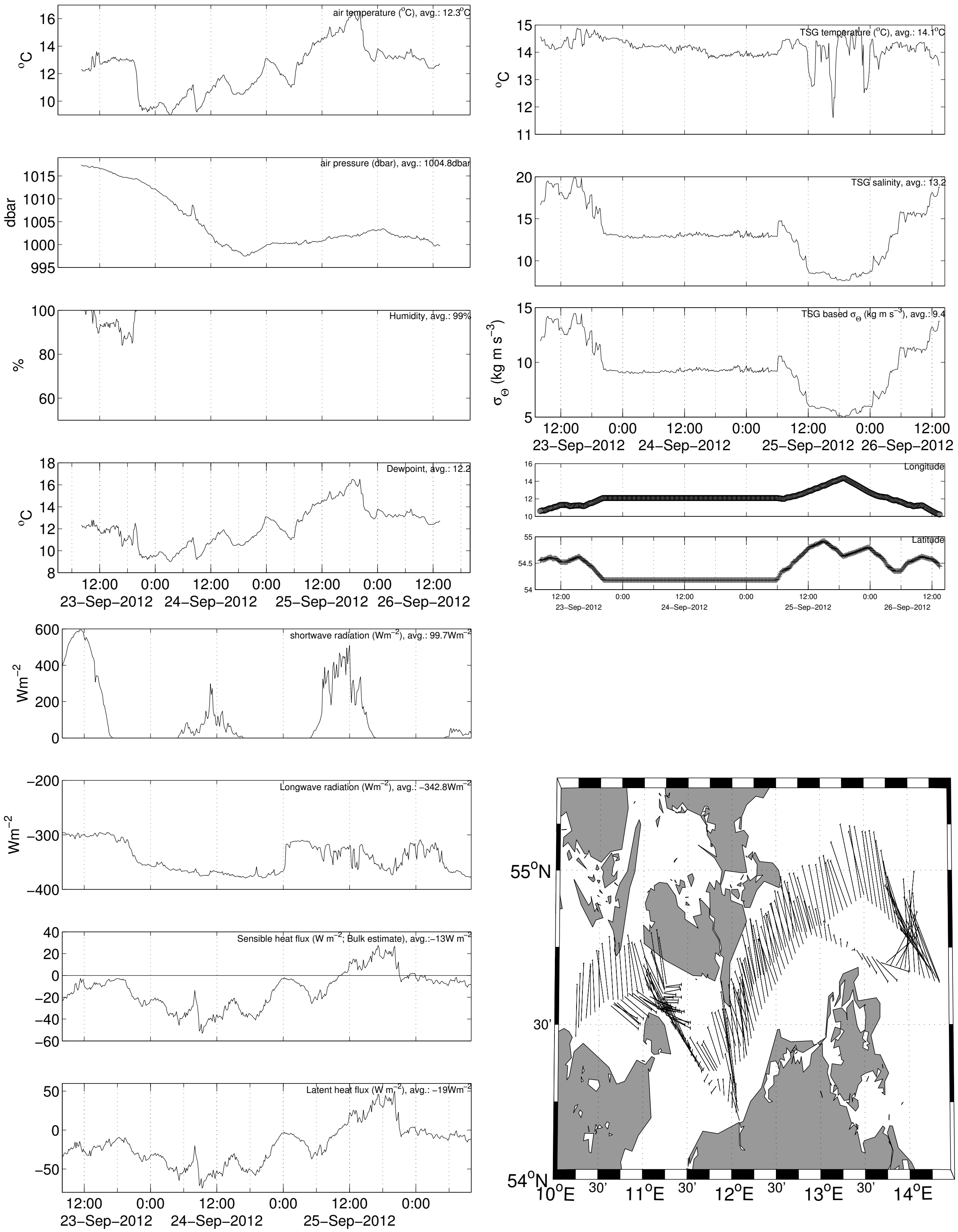

Figure 4.4: *Various meteorological observed and derived parameters.*

4.3 Mooring

The V431 is installed in the Speergebiet Marienleuchte since 2002. During Al03-12 the mooring could not be recovered from its 22th deployment, as it did not appear at the surface. The 22th deployment was done with the RV Littorinia on the 18. July 2012. On the 24. October the RV Deneb (BSH) search and found the bottom shield at the deployment location but upside down. The data analysis revealed that the shield already landed upside down. A new installation was done on the 4th December 2012, again with RV Littorina.

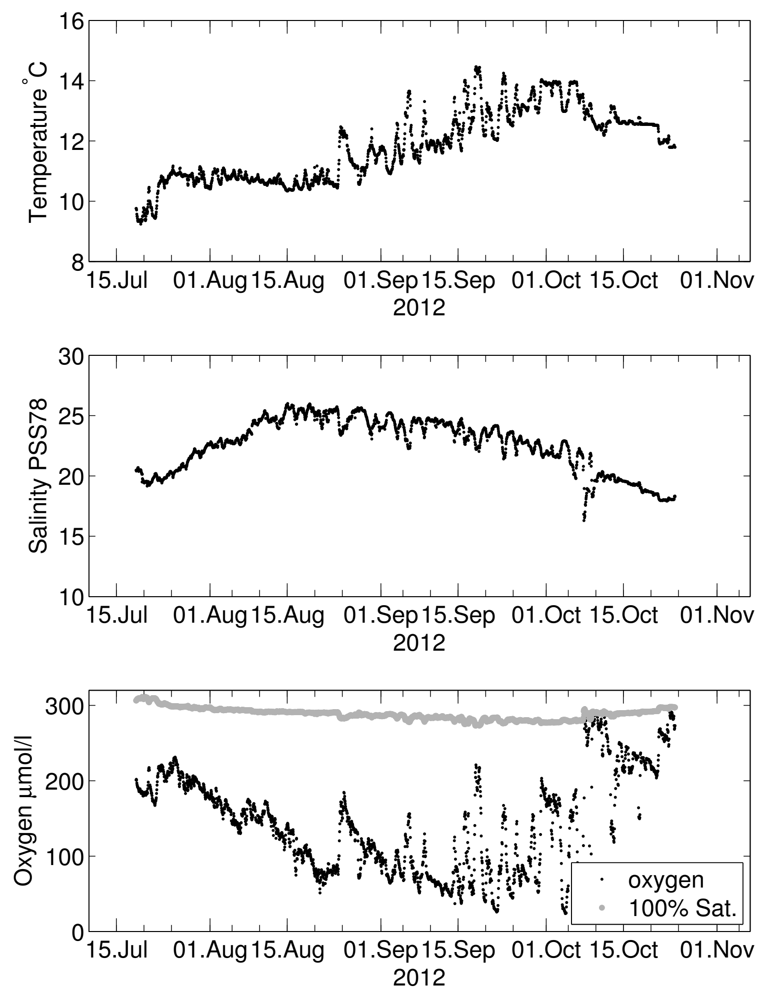

Figure 4.5: *(upper) temperature, (middle) salinity, and (lower) oxygen from RDCP 600 at V431 position at 28m water depth. Note the instrument was placed upside down and no velocity informtion was recorded. Deployment in July 2012 - recovery (by diver) in Decmber 2012.*

The time series of T/S/O2 over a period of a couple of month show for T/S mainly a certain part of the seasonal cycle. As the instrument is at about 28m water depth the warming continues

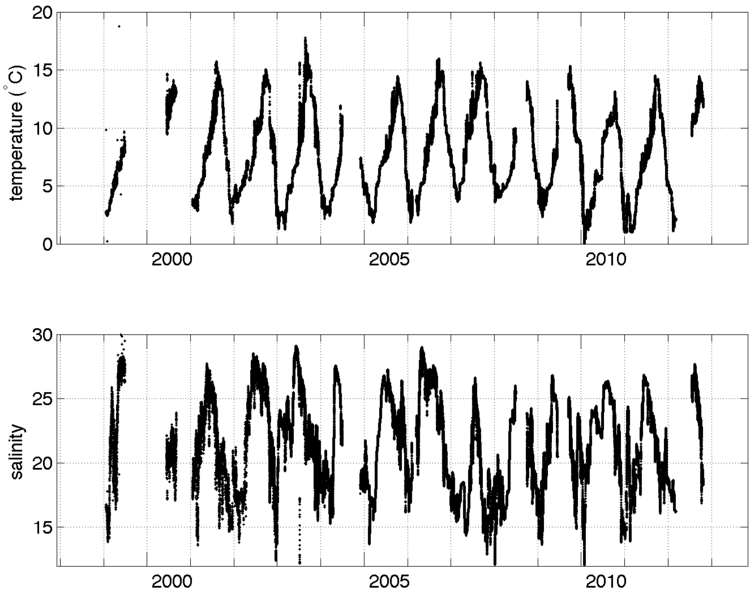

Figure 4.6: *(upper) temperature and (lower) salinity between 1999 and 2012 at the bottom (28m) of the Fehmarn Belt.*

until the beginning of October. The oxygen concentration at the bottom (4.5, lower) are reaching surprisingly low values by the end of summer, with the onset of the heat loss and deeper mixing the oxygen content quickly increases and reach saturation by end of October.

Time series of bottom water temperature and salinity (Figure 4.6) show a clear seasonal cycle in T and S (and also in density). Warmest temperatures of more than 16°C were recorded in autumn 2003, coldest in the winter 2010/2012.

Chapter 5

Equipment/instruments

5.1 Technical: Mooring V431

Mooring deployment site V431 is located in the military zone of Marienleuchte at the south-eastern opening of the Fehmarn Belt. Water depth is about 28m. V431 consists of a Aanderaa RDCP600, serial 227 with temperature (serial 2639, type:3621), conductivity (serial 85, type: 4019A), oxygen Optode (3830) and a self containing T/S recorder of type SBE-MicroCat (serial number 2936). The ADCP and all other parameter logging was programmed for every hour, the MicroCat (not recovered yet) record every 15 minutes.

The Aanderaa RDCP600 is configured for current recordings in 1.5m depth cells covering the whole water column. So far no 100% successful deployment can be reported, and agin we had a problem with the battery power during the deployment - as the battery seem to be not able to last long enough (1 year) although the battery calculator indicates. This could be due to the lower power availability of the lithium batteries in cold waters (nominal energy density is calculated against 20°C).

5.2 Salinometer Measurements

The conductivity sensor of the CTD was calibrated against water samples analysed with a Beckmann Salinometer. For demonstration purposes, two calibrations of the Beckmann salinometer were done againts IAPSO standard seawaterat. During the cruise frequent calibration against a so called "sub-standard" was done - a large volume of water with constant, but unknown, salinity. This volume was sampled to detect a drift in the Beckmann salinometer. Besides, the CTD sonde samples from the TSG were also analysed.

Before analysising the water samples, they had to stay one night at the laboratory to adapt to the room temperature. Furthermore the Beckmann Salinometer needs to be expurgated before each salinity measurement twice with sample water for higher accuracy. We measured each sample until two measurements had a precision of 0.01. The mean salinity value of these two measurements was considered to be the final value.

5.2.1 Substandard

The substandard water was measured directly after the calibration and later on after about every third water sample in order detect a possible drift of the Salinometer. Considering all measurements from the first substandard water which were less than three times standard deviation off the mean value, to determine a time or temperature dependence of the Salinometer. The mean value of this substandard water is 20.39 while the standard deviation is 0.0258. There is no time or temperature dependence of the Salinometer (Figure 5.1) so we do not have to correct the measurement of the water samples for a drift. A second substandard water was taken on the third day of the cruise. The 2nd substandard had a mean salinity of 14.77 but the few measurements of this substandard do not allow for good statistics.

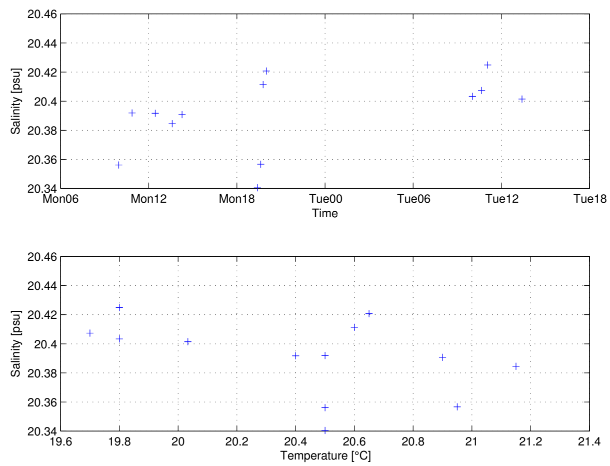

Figure 5.1: *Substandard Measurements (upper) against time, (lower) against temperature of sample.*

5.2.2 Calibration of CTD

To determine the accuracy of our CTD-measurements we took several water sample at each station. For every water sample the CTD extracted the according dataset from the profile. We determined the salinity of these samples by using the Beckman Salinometer. We then took the difference in salinity of these samples to the according CTD measurements (Figure 5.2). The mean difference of all measurements is -0.2883 and 11 out of 14 measurements lie within the standard deviation of 2.34. No significant drift was detected. Compared to the the standard deviation of the Salinometer of 0.03 this deviations is one magnitude higher. To account for contaminated water samples by contact to skin or other careless handling, we discharged all measurements that were one time the standard deviation of the mean value. This procedure reduced the standard deviation to 0.995 and the new mean value is -0.1407. To make sure not to miss any significant dependencies, further data processing was done with both datasets. But as no significant results were obtained, only the reduced datasets are shown. There is no need to correct the CTD-Data at this point.

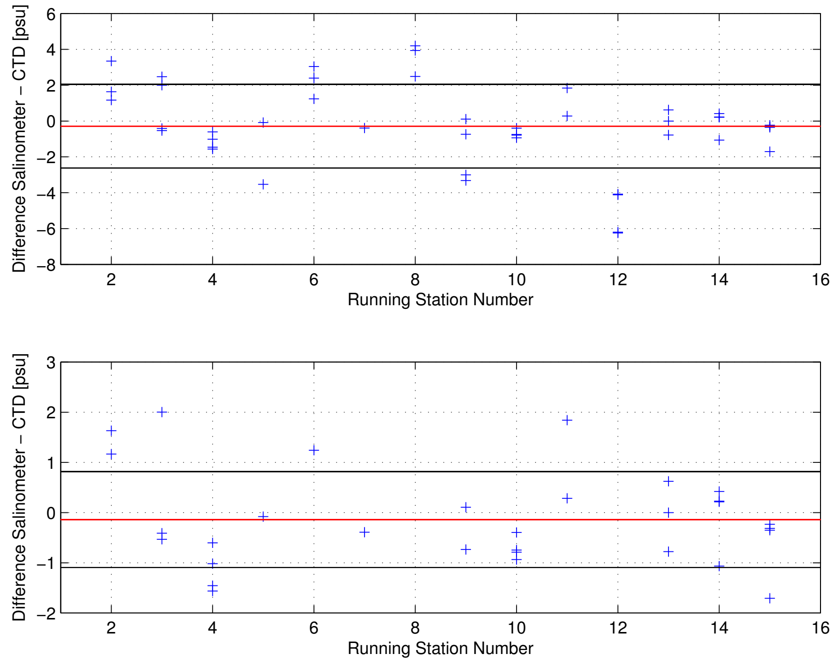

Figure 5.2: *Difference between Salinometer Measurements and corresponding CTD Measurement; Blue Crosses: Differences; Black: Standard Deviation; Red: Mean; Above: Complete dataset; Below: Reduced dataset.*

To evaluate if the conductivity sensor of the CTD is affected by pressure we ploted the difference of CTD and salinometer against pressure measured by the CTD. (Fig. 5.2) For higher pressure there are smaller differences so the salinity measured by the CTD is higher. We have calculated a linear trend of -0.1791 per dbar for the CTDs dependence on pressure. Because we can assume that the salinometer does not depend on the pressure at which the water sample was taken this drift is exclusively of the CTD salinity measurement. So the salinity measured by the CTD rises by 0.18 per dbar pressure.

Another way of checking our instruments is shown in figure 5.2. Here the difference in salinity between the Salinometer and the CTD is plotted against total salinity. That way we can test whether one of the measuring methods has a dependence on salinity and varies more at higher or lower salinities. The highest absolute differences can be found at 18-21 but due to a large standard deviation there is no significant trend observable. The difference values are distributed equally around the mean and positive or negative differences have almost the same absolute value. So we can assume that neither the Beckmann Salinometer nor our Hydro Bios CTD has a significant dependence on salinity. For a more accurate conclusion we would have to look at at a more comprehensive dataset.

Another source of error could be strong salinity-gradients in the depth were the samples were taken. As the Rosette-Bottles take water from a different depth than the CTD measures salinity there might be a difference between both measurements for strong gradients. We determined the salinity-gradient in the surrounding water from one meter above and one meter below the CTD.

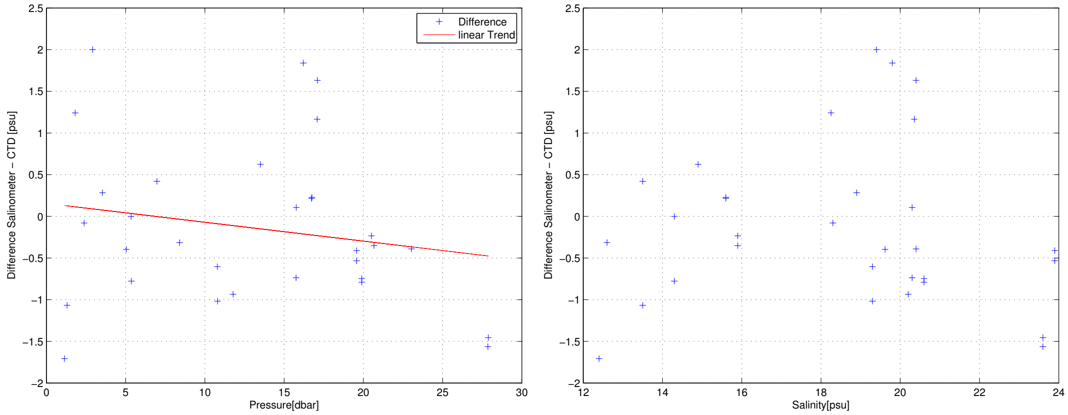

Figure 5.3: *CTD/Beckmann difference against (left) pressure and (right) salinity.*

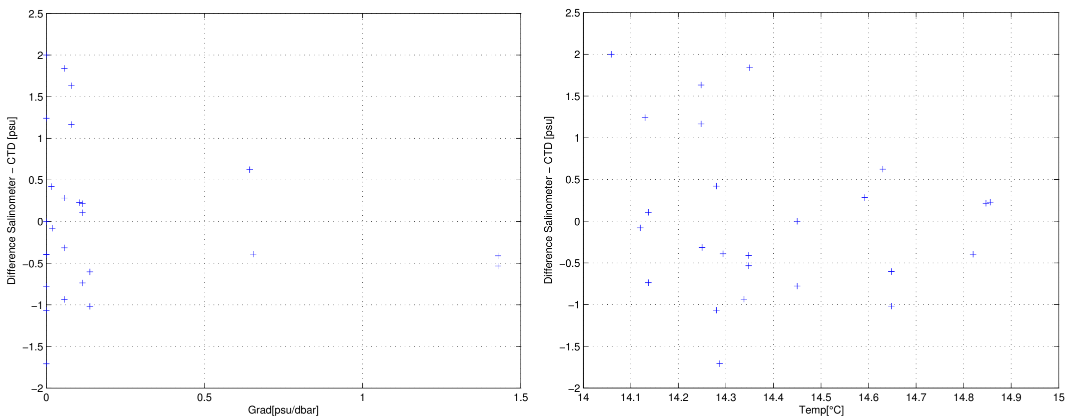

Figure 5.4: *CTD/Beckmann difference against (left) salinity gradient and (right) temperature.*

We then plotted the difference between salinometer and CTD measurement against the salinity gradient. (Fig. 5.4) The majority of gradients are small, less than 0.2 psu/dbar, only a few are greater. There is no obvious dependence of the difference from the gradient. Because there are big differences between the two salinity measurements for small gradients and for greater gradients the differences are within the range of the standard derivation around the mean value.

Finally we looked at the difference distribution compared to temperature. This way we can analyze whether the big differences between the Beckmann Salinometer and the Hydro Bios CTD measurement have a dependence on temperature. The result is shown in Fig. 5.4. Again there is no significant trend observable and we can assume that our measurements have no dependence on temperature.

5.3 Underway Measurements

5.3.1 WERUM

ALKOR has a new central data collection system from WERUM. The system worked perfect during the cruise and facilitated our work in providing on-line cruise map, a downloadable station book as well as export of relevant data. The WERUM is a substitute for the former 'DATADIS' system that caused a lot of trouble during the last years and we are very happy that this new WERUM system was installed on ALKOR.

5.3.2 Navigation

ALKOR has a GPS navigational system as well as a gyro compass available and distributed via WERUM. The WERUM map viewer allowed to follow the cruise track online.

5.3.3 Meteorological Data

Since March 2006 ALKOR is equipped with a so called automatic weather station which should acquires the basic meteorological parameters (air temperature, wind speed and direction, wet-temperature, humidity, air-pressure). Shortwave radiation is also measured. Long wave radiation is recorded with an EPLAB (Eppley Laboratory, Inc.) Precision Infra-red Radiometer (Model PIR).

5.3.4 Echo sounder

The ER 60 SIMRAD echo sounder was activated during the cruise.

5.3.5 Thermosalinograph

The thermosalinograph (TSG) on ALKOR is permanently installed at about 4m depth,takes up about one litre per second.

5.3.6 Vessel mounted ADCP

A 600kHz workhorse ADCP from RD Instruments was mounted in the ships hull. The vmADCP is used with bottom tracking mode. Navigational data (including ships heading) is available via a THALES 3011 dGPS system. The connections have been corrupt after the last ship yard visit of the ALKOR and some recalibration had to be done during the cruise.

Chapter 6

Acknowledgement

A big thank to Norbert Hechler (master), Rainer Nannen (1st) and all crew members of RV ALKOR for a successful and comfortable cruise.

Chapter 7

Appendix

Station table

st	lat	long	depth	year	month	day	hour
1	54.5647	10.6673	20	2012	09	23	8.52
2	54.6085	10.9160	22	2012	09	23	9.92
3	54.5918	11.0830	32	2012	09	23	10.87
4	54.5225	11.3043	28	2012	09	23	11.85
5	54.5468	11.1635	10	2012	09	23	13.75
6	54.5658	11.1847	28	2012	09	23	14.08
7	54.5832	11.2080	27	2012	09	23	14.40
8	54.5998	11.2252	27	2012	09	23	14.80
9	54.6122	11.2410	24	2012	09	23	15.13
10	54.6252	11.2583	20	2012	09	23	15.45
11	54.4500	11.4992	24	2012	09	23	17.73
12	54.3563	11.9985	18	2012	09	25	7.17
13	54.3993	12.1665	21	2012	09	25	8.05
14	54.5323	12.3023	24	2012	09	25	9.33
15	54.6332	12.4998	18	2012	09	25	10.45
16	54.8087	12.9165	19	2012	09	25	12.33
17	54.8590	13.1997	42	2012	09	25	13.53
18	54.9167	13.5012	46	2012	09	25	14.93
19	54.7822	14.0018	38	2012	09	25	17.12
20	54.6337	14.3342	32	2012	09	25	18.82
21	54.3497	11.8338	22	2012	09	26	5.07
22	54.3498	11.6665	25	2012	09	26	5.78
23	54.5475	11.1628	12	2012	09	26	8.38
24	54.5667	11.1842	28	2012	09	26	8.68
25	54.5843	11.2062	28	2012	09	26	9.02
26	54.6002	11.2250	28	2012	09	26	9.40
27	54.6120	11.2410	24	2012	09	26	9.67
28	54.6253	11.2585	20	2012	09	26	9.97